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## Poster paper

# Overview of diagnostics and instrumentation for National Synchrotron Light Source II

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National Synchrotron Light Source II (NSLS-II), a new state-of-the-art third-generation light source under construction at Brookhaven National Laboratory is expected to have extremely small emittance and extraordinary beam stability. The mechanical requirements for beam diagnostics and instrumentation are exceptionally challenging. Here we present an overview of the mechanical aspects of some NSLS-II diagnostics as well as the performance levels of some systems currently under development.

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## 1. Introduction

A new third-generation 3 GeV synchrotron light source, the National Synchrotron Light Source II (NSLS-II) currently under construction at Brookhaven National Laboratory will require state-of-the-art beam diagnostics in order to provide an unprecedented level of beam stability and brightness. The extremely small emittance expected at NSLS-II imposes strict mechanical requirements on many of the diagnostic elements, particularly with the beam position monitor (BPM) system. Considerable effort is being given to provide exceptional thermal and mechanical stability to many of the storage ring diagnostic elements.

## 2. Standard radio frequency beam position monitors

The NSLS-II standard radio frequency (RF) BPM configuration consists of six BPMs per cell, mounted on multi-pole vacuum chambers with a 25 mm vertical aperture. Optimization of the horizontal and vertical sensitivity requirements resulted in a geometry with two 7 mm diameter buttons separated by 16 mm (figure 1*a*). The small spacing between buttons dictated a dual button design, i.e. two pick-up electrodes in a common body.

There were several engineering challenges that surfaced during the design phase, one of which was minimizing the trapped mode heating of the BPM buttons (Pinayev & Blednykh). The thermal expansion of the buttons that would result from trapped mode heating would have a negative impact on vertical beam stability. Considerable

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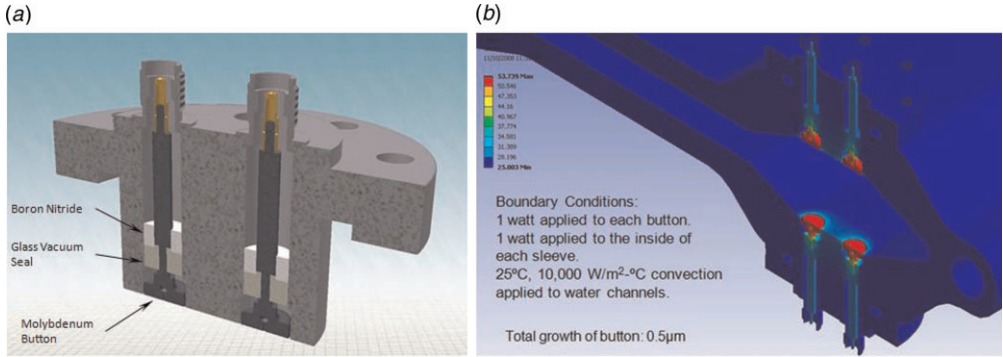


FIGURE 1. (a) BPM dual button geometry. (b) Steady-state thermal simulation of trapped mode button heating.

effort was given to mitigate this problem. Molybdenum was chosen for the button and fed through the electrode for its inherently low resistivity and thermal expansion coefficient. In addition, a conductive heat path was added in the form of a boron nitride washer to sink any generated heat into the stainless body and aluminium vacuum chamber. Finite-element simulation revealed that the trapped mode heat results in negligible thermal deformation (figure 1b) (Cameron).

### 3. User (high stability) BPM supports

An important aspect of the NSLS-II BPM system is the use of mechanically isolated, high-stability BPM supports located at both ends of the short insertion device straight sections. The vertical beam size at this location is expected to be  $\sim 3 \mu\text{m}$ . In order to measure the beam position to a resolution of 10 % of the beam size, the thermal stability requirements for the BPM was specified as  $\pm 100 \text{ nm}$ . The design ultimately chosen to satisfy this requirement consists of an array of four 50 mm diameter invar rods with steel spacer plates to give the structure high rigidity. The low diffusivity of invar and low surface area-to-volume ratio of the rods resulted in a temperature response of  $\pm 0.015$  to  $\pm 0.1^\circ\text{C}$  ambient air. This combined with the low coefficient of thermal expansion (CTE) of invar yielded an exceptionally high thermal stability of the order of  $\pm 50 \text{ nm}$ , satisfying the requirement by a factor of 2 (Kosciuk).

### 4. Mitigation of rogue modes in multi-pole vacuum chambers

The geometry of the NSLS-II vacuum chambers can generate transverse electric field modes with frequencies above 450 MHz. Higher-order modes generated in the 500 MHz band of NSLS-II BPMs can introduce systematic errors in the beam position. Mitigating this issue involved shifting high-order modes to higher frequencies by incorporating microwave RF shields into the vacuum chamber assemblies (figure 2) (Blednykh).

### 5. Pinhole camera beamlines

Preliminary design layouts are in progress for bending magnet and three-pole wiggler pinhole camera beam lines for the purpose of measuring beam size,



FIGURE 2. (a) Location of RF shield in a multi-pole chamber. (b) S21 measurement showing a frequency shift of HOM to 900 MHz.

horizontal emittance and energy spread. These designs consist of a reduced (5 mm) aperture crotch absorber, a 300  $\mu\text{m}$  diamond window, horizontal/vertical imaging slits with compound refractive lenses on X-Y stages followed by multi-layered mirrors. Images are captured by high-resolution gigabit cameras.

## 6. Photon beam position monitors

A preliminary design of an X-ray BPM is currently under consideration. The design consists of a blade-type BPM from FMB Oxford (Oxford, UK) mounted on top of a high-resolution X-Y stage developed at Brookhaven National Laboratory (BNL). A high-stability invar support will provide better than  $\pm 200$  nm thermal stability for the system.

## 7. Injector diagnostics

Although the linear accelerator (LINAC) and booster are turn-key procurements, NSLS-II diagnostics is responsible for providing instrumentation for measuring critical beam parameters for these as well as both transport lines (Padrazzo). Transport line BPM pick-up electrodes have been designed using a 15 mm-diameter button geometry mounted in a 40 mm round vacuum chamber. One exception is the BPM in the high-dispersion region on the LINAC to booster the transport line where a 40 mm  $\times$  90 mm elliptical chamber is required.

There will be a series of intercepting diagnostic flags in the LINAC and both transport lines. The design consists of a both Yttrium-aluminum-garnet (YAG) and optical transition radiation (OTR) screens coupled to a three position vacuum feed through an actuator and housed in a six-way cube. An optical transport and hi-res gigabit camera will provide image capture.

There are two energy slits, one in each transport line consisting of a pair of phosphor-coated tungsten blades housed in a six-way vacuum cross. The blades are coupled to stepper-driven linear actuators via a pair of edge-welded bellows.

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